3 AFFECTED ENVIRONMENT

This chapter describes the environment that will be affected by the resumption of L-Reactor operations. Major emphasis is placed on areas that past operations have shown to have the greatest potential for being affected. Much of this material was covered in the Environmental Assessment, L-Reactor Operation (DOE, 1982a).

3.1 GEOGRAPHY

3.1.1 Site location

The Savannah River Plant (SRP), including the L-Reactor, is located in southwestern South Carolina. The plant occupies an almost circular area of approximately 780 square kilometers, bounded on its southwestern side by the Savannah River, which is also the Georgia-South Carolina border. Figure 3-1 presents the site location in relation to major population centers, the closest being Augusta, Georgia, and Aiken and Barnwell, South Carolina.

The locations of various facilities of the Savannah River Plant are shown in Figure 3-2. The L-Reactor site is located in the south-central portion of the SRP, about 5 kilometers from South Carolina Highway 125 and 9 kilometers from the nearest plant boundary. Three small South Carolina towns, Snelling (population 111), Jackson (population 1771), and New Ellenton (population 2628), and the City of Barnwell (population 5572) lie within 25 kilometers of L-Reactor. Chem-Nuclear Systems, Inc., and the Barnwell Nuclear Fuel Plant (currently not expected to operate), which is owned by Allied-General Nuclear Services, are about 25 kilometers east of L-Reactor; the Vogtle Nuclear Power Plant is approximately 15 kilometers to the west-southwest.

3.1.2 Site description and land use

The Atomic Energy Commission, a predecessor agency to the U.S. Department of Energy (DOE), selected the location of Savannah River Plant in November 1950, after studying more than 100 potential sites. Criteria used in the selection of the site included the low population density, the accessibility of a large cooling water supply, and the low frequency of floods and destructive storms (DOE, 1980). The construction of SRP facilities began in February 1951, and eventually involved more than $1 billion in expenditures with a peak construction force of 38,500 workers.

The Savannah River Plant is a controlled area with public access limited to through traffic on South Carolina Highway 125 (SRP Road A), U.S. Highway 278, and SRP Road 1; the Seaboard Coast Line Railroad; approved tour groups; forest management activities; controlled hunting; and environmental studies. Access to Savannah River Plant is also permitted for organized deer hunts, which began in 1965 to help control the deer population.

The SRP facilities include five nuclear production reactors (three currently operating), two chemical separations areas, a fuel and target fabrication facility, a heavy-water production facility (on standby except for rework), and various supporting facilities (Figure 3-2). Onsite waste-disposal facilities include tank farms near the chemical separations areas for storage of high-level waste and a 195-acre burial ground for low-level radioactive waste. Construction is underway on the Fuel Materials Facility (F-Area) and the Defense Waste Processing Facility (north of H-Area).

The Savannah River Plant is located in the Aiken Plateau physiographic division of the Coastal Plain of South Carolina. Due to the plant's proximity to the Piedmont region, it has somewhat more relief than the near-coastal areas, with onsite elevations ranging from 27 to 104 meters above mean sea level. This area is underlain by the Tuscaloosa aquifer, which supplies well water to several operating areas of the Savannah River Plant, including L-Reactor. Par Pond is a man-made cooling impoundment; cooling water from the operating reactors is discharged either to this impoundment (P-Reactor at present and R-Reactor before it was placed on standby) or to one of the SRP streams (C-Reactor to Four Mile Creek and K-Reactor to Pen Branch at present and L-Reactor to Steel Creek before it was placed on standby), all of which drain to the Savannah River.

K- and P-Reactors are approximately 4 kilometers to the west and east-northeast of L-Reactor, respectively. C-Reactor is about 7 kilometers northwest of L-Reactor, and R-Reactor is 8 kilometers northeast of L-Reactor.

3.1.3 Historic and archeological resources

In 1982, 62 sites in the study area (Section 3.2.2) were listed in the National Register of Historic Places (see Appendix E). Richmond County had the largest number of sites (26), most of which are in the City of Augusta. Approximately 20 more National Register sites are in Aiken and Allendale Counties. Fifteen of the 62 sites are within 15 kilometers of the Savannah River Plant.

During January and February 1981, a survey was conducted of the Steel Creek terrace and floodplain system below L-Reactor for archeological resources and sites that might qualify for inclusion in the National Register of Historic Places (Hanson et al., 1982). The area of Steel Creek surveyed was 13 kilometers long and 300 meters wide. Archeologists traversed the first and second terraces of the creek system, inspecting 4-square-meter plots every 5 meters along the creek. Sites found were divided into three groups--those significant (i.e., eligible for nomination to the National Register of Historic Places), those potentially significant, and those not significant.

The survey identified 18 historic and archeological sites along Steel Creek below L-Reactor. One archeological site, located at the confluence of Steel Creek and Meyers Branch, was considered significant in terms of National Register criteria. It could yield important data on relatively uninterrupted prehistoric occupation that began in the Early Archaic Period (9500-7500 B.C.) and continued through the Mississippian Period (A.D. 1000-1700). In July 1982, the DOE requested the concurrence of the Keeper of the National Register on this site's eligibility for nomination to the National Register. The Keeper concurred in this site's eligibility.

Seven other sites were also considered potentially significant in terms of National Register criteria. Three of these sites occur beyond the area of potential effects from increased water levels in Steel Creek due to L-Reactor operation. The remaining four sites include three mill dams that date to the early nineteenth century and an historic roadway across the Steel Creek floodplain. In July 1982, the DOE requested the concurrence of the Keeper of the National Register regarding the eligibility of these sites for nomination to the National Register. The Keeper of the National Register concurred in the eligibility of these four sites for inclusion in the National Register. A monitoring and erosion protection plan has been implemented for all sites eligible for inclusion in the National Register. TC

The remaining 10 sites were not considered significant in terms of National Register criteria. These are archeological sites, dating possibly as far back as 6000 B.C., that are lacking in integrity or are too limited in content to permit the acquisition of additional data. They were not considered eligible for nomination to the National Register.

Figure 3-3 shows the location of the five sites that have been determined to be eligible for inclusion in the National Register.

In March 1984, an intensive survey of the proposed excavation areas (embankment and borrow pit areas) was made (Brooks, 1984). This survey identified seven sites described as of ephemeral quality and not eligible for nomination to the National Register of Historic Places.

Archeological surveying and testing are presently being conducted in the proposed lake area by the University of South Carolina Institute of Archeology and Anthropology. It is anticipated that several sites associated with the Ashley Plantation will be affected. The schedule for completion of the requirements under the National Historic Preservation Act, including data recovery, is consistent with the construction schedule for the embankment, and all mitigation will be completed prior to restart (Hanson, 1984). TC

3.2 SOCIOECONOMIC AND COMMUNITY CHARACTERISTICS

A comprehensive characterization of socioeconomic and community characteristics around the Savannah River Plant was undertaken for the DOE in 1981. Additional information on the topics presented in this section can be found in the Socioeconomic Baseline Characterization for the Savannah River Plant Area, 1981 (ORNL, 1981) and the Final Environmental Impact Statement, Defense Waste Processing Facility, Savannah River Plant, Aiken, South Carolina (DOE, 1982b).

3.2.1 Past impacts of Savannah River Plant

The socioeconomic impacts of the Savannah River Plant (SRP) on the people and communities in its vicinity began with the relocation of the resident population from the SRP site and construction of the first facilities in 1951. By 1952, a peak construction workforce of 38,500 was onsite. Populations of the nearby towns increased, and the number of trailer courts and new homes increased rapidly. These early days and the changes induced by plant construction are described in In the Shadow of a Defense Plant (Chapin et al., 1954).

The primary socioeconomic impact of the Savannah River Plant since the completion of initial construction has been the large number of permanent jobs created. The permanent operating and construction force has averaged 7500, ranging from a low of 6000 in the 1960s to the current 9200 (December 1982). About 97 percent of this total are employed by E. I. du Pont de Nemours and Company and its subcontractors; the remainder are employed by the U.S. Department of Energy (221), the University of Georgia (55), and the U.S. Forest Service (22).

The greatest impact of the Savannah River Plant has been on Aiken County, especially the City of Aiken, and the small towns immediately around the SRP site, as listed in the SRP worker distribution pattern in Table 3-1. SRP workers and families comprise roughly one-half of the City of Aiken's 15,000 people and account in large measure for the high median family incomes in Aiken County.

3.2.2 Study area

Approximately 97 percent of SRP employees reside in a 13-county area surrounding the Savannah River Plant. Of these 13 counties, 9 are in South Carolina and 4 are in Georgia. The greatest percentage of employees now reside in the six-county area of Aiken, Allendale, Bamberg, and Barnwell Counties in South Carolina, and Columbia and Richmond Counties in Georgia (Figure 3-4). Together these six counties house approximately 89 percent of the total SRP workforce. Because any new L-Reactor operating employees will reside in a distribution similar to that listed in Table 3-1, these six counties were chosen as the study area for the assessment of potential socioeconomic and community effects.

3.2.3 Demography

3.2.3.1 Study area population

Table 3-2 lists the 1980 populations in the study area for counties and places of more than 1000 persons. The largest cities in the study area are Augusta in Georgia, and Aiken, North Augusta, and Barnwell in South Carolina. Of the 31 incorporated communities in the study area, 16 have populations under 1000 persons, and 11 have populations between 1000 and 5000 persons. Aiken, Columbia, and Richmond Counties, which comprise the Augusta Standard Metropolitan Statistical Area (SMSA), have a total population of about 327,400; however,

Table 3-1. Distribution of SRP employees by place of residence

Location of residence	Percent of SRP labor force
South Carolina	80.0
Aiken County	58.8
Allendale County	1.8
Bamberg County	2.0
Barnwell County	8.8
Edgefield County	1.1
Hampton County	1.2
Lexington County	1.6
Orangeburg County	1.7
Saluda County	1.0
Other counties	2.0
Georgia	19.9
Columbia County	3.1
Richmond County	14.8
Burke County	0.3
Screven County	0.8
Other counties	0.9
Other states	0.1
Total	100.0

most of this population resides outside cities or towns. About two-thirds of the total six-county population resides in rural or unincorporated areas.

Over the last three decades, the rate of population growth has varied dramatically from county to county. From 1950 to 1980, the counties comprising the Augusta SMSA experienced a positive growth rate; the combined average annual rate was about 3 percent. The most significant population increases occurred in Columbia County, which experienced an average growth rate between 1960 and 1980 of about 10 percent per year. The rural counties--Allendale, Bamberg, and Barnwell--experienced population declines between 1950 and 1970; reversals of this decline occurred between 1970 and 1980 when population increases for these counties ranged from 9 to 16 percent. The population growth rate experienced in the study area during the last two decades was about equal to that experienced in the southern United States and slightly less than the growth rate experienced in the South Atlantic Region (Bureau of the Census, 1983).

Population densities in the study area ranged from a low in 1980 of 10 persons per square kilometer in Allendale County to a high of 215 persons per square kilometer in Richmond County. The 1980 average population density of about 47 persons per square kilometer for the study area is less than the 53.5 persons per square kilometer for the South Atlantic Region of the United States (Bureau of the Census, 1983).

Table 3-2. 1980 population for counties and places of 1000 persons or greater[a]

Location	1980 population
Aiken County, South Carolina	105,625
City of Aiken	14,978
Town of Jackson	1,771
City of North Augusta	13,593
City of New Ellenton	2,628
Allendale County, South Carolina	10,700
Town of Allendale	4,400
Town of Fairfax	2,154
Bamberg County, South Carolina	18,118
Town of Bamberg	3,672
City of Denmark	4,434
Barnwell County, South Carolina	19,868
City of Barnwell	5,572
Town of Blackville	2,840
Town of Williston	3,173
Columbia County, Georgia	40,118
City of Grovetown	3,384
City of Harlem	1,485
Richmond County, Georgia	181,629
City of Augusta	47,532
Town of Hephzibah	1,452
Study area total	376,058

[a]Adapted from the Bureau of the Census (1982a,b).

During the last 30 years, the population in the study area has tended to be slightly younger than the national average, despite a slight increase in the median age between 1970 and 1978. The birth rates in the six-county area have also tended to be somewhat higher than the national average.

3.2.3.2 Regional population

In 1980 the estimated population in the 80-kilometer area around the Savannah River Plant was approximately 563,300 persons. The year 2000 population in this area is estimated at 852,000 persons. This estimate was calculated utilizing the 1970-to-1980 growth rate of each county in the 80-kilometer area, assuming these growth rates would continue in the future. For counties that experienced a negative population growth rate between 1970 and 1980, the calculation assumed that no continued population decline would occur. This total county population estimate for the year 2000 is approximately 12 percent higher than the estimates prepared by the States, based on a comparison with projections prepared by Georgia and South Carolina.

3.2.3.3 Transient population

The transient population within 16 kilometers of the L-Reactor consists of the SRP workforce; a total of 8864 personnel (July 1983) at the Vogtle Nuclear Power Plant, which is currently under construction; and about 300 personnel working for Chem-Nuclear Systems, Inc. The Barnwell Nuclear Fuel Plant, which is owned by Allied General Nuclear Services, is expected to maintain only a guard force.

The SRP workforce is expected to increase due to construction of the proposed Defense Waste Processing Facility and other ongoing activities. Therefore, in the mid-1980s, the SRP workforce could be near 12,600, decreasing to about 8500-9000 personnel in the mid-1990s.

Recreational hunting and camping account for about 10,000 visitor-days within a 24-kilometer radius of L-Reactor. Travelers crossing Savannah River Plant on U.S. Route 278 and South Carolina Highway 125 and on the Seaboard Coast Line Railroad add about 20,800 person-days to the 16-kilometer transient population (Du Pont, 1982a).

There are no schools, military reservations, hospitals, prisons, or airports within the 16-kilometer radius from L-Reactor.

3.2.4 Land use

In the study area near Savannah River Plant, less than 5 percent of the existing land-use pattern is devoted to urban and built-up uses. Most land uses of these types are in and around the Cities of Augusta, Georgia, and Aiken, South Carolina. Agriculture accounts for about 24 percent of total land use; forests, wetlands, water bodies, and unclassified lands that are predominantly rural account for about 70 percent of total land use.

All the counties in the study area except Allendale have zoning ordinances, and all except Bamberg have approved land-use plans. Of the land-use controls most commonly used by communities (i.e., zoning, subdivision regulations, land-use plans, building codes, and mobile home/trailer park regulations), 22 of the 31 incorporated jurisdictions in the study area have at least one type of regulation.

Less than 5 percent of the total SRP land area, including the L-Reactor site, is used by facilities engaged in the production of defense nuclear materials. Reservoirs and ponds comprise approximately 3000 acres on the SRP site. The remainder is composed of natural vegetation and pine plantations that are managed by the U.S. Forest Service under a cooperative agreement with DOE.

3.2.5 Public services and facilities

There are nine public school systems in the study area. County-wide school districts are located in each county except Bamberg, which has two districts, and Barnwell, which has three. In 1980, all school districts, except Allendale, reported available classroom space to accommodate a total of 8600 new students. The Aiken and Richmond County school districts reported the greatest capacity, with space for about 3600 and 2600 new students, respectively.

Of the 120 public water systems in the study area, 30 county and municipal systems serve about 75 percent of the population. The other 90 systems are generally smaller and serve individual subdivisions, trailer parks, or commercial and industrial enterprises. All but four of the municipal and county water systems--the Cities of Aiken, Augusta, and North Augusta, and Columbia County--obtain their water from deep wells. For those municipal and county water systems that use ground water as their supply, restrictions in system capabilities are primarily due to storage and treatment capacity rather than availability of ground water.

Most municipal and county wastewater-treatment systems have the capacity to treat additional sewage. Selected rural municipalities in Allendale, Bamberg, and Barnwell Counties and the City of Augusta in Richmond County have experienced problems in treatment-plant capacities. Programs to upgrade facilities are under way or planned in most of these areas.

3.2.6 Housing

Since 1970, the largest increases in the number of housing units have occurred in Columbia, Aiken, and Richmond Counties. Columbia County has grown the fastest, nearly doubling its number of housing units. Between 1970 and 1980, Aiken and Richmond Counties each experienced about a 36-percent increase in the number of housing units. In Aiken County, half of this increase resulted from the high growth rate in the number of mobile homes.

Vacancy rates for owner-occupied housing units for Richmond and Columbia Counties in 1980 were 4 and 3 percent, respectively, while vacancy rates for the South Carolina counties in the study area ranged from a low of 1 percent in Barnwell County to a high of 1.5 percent in Aiken County. Vacancy rates for rental units were the highest in Richmond County (15 percent), while the remaining counties ranged between 7 to 12 percent.

3.2.7 Economy

Nonfarm employment in the study area is concentrated in the manufacturing industries. Manufacturing constitutes the largest employment category in each county except Richmond County. Significant percentages of employment in retail and wholesale trade establishments also exist in Allendale and Richmond Counties.

Agriculture and agricultural employment is an important element in the economy of each county. In 1978, Allendale County had the highest average value of products sold per farm--about $58,500--while Columbia County had the lowest average--about $10,000.

Employment levels in the study area have increased in recent decades as both the total labor force and participation rates have increased. Per capita incomes in Aiken and Richmond Counties were the highest in the study area, and in 1974 ranked in the top 50 percent of the national averages. Most of the other counties, however, ranked in the bottom 11 percent of the national averages.

The substantial contribution of Savannah River Plant to the rise in the standard of living in the study area has been a major socioeconomic benefit. The FY 1983 operating budget is $864 million with the FY 1984 budget expected to be about $1.1 billion. In FY 1983, $370 million will be paid as direct wages and salaries. Local purchases are expected to be approximately $20 million. Of the total FY 1982 purchases of $247 million, about $10 million was spent with disadvantaged businesses and $100 million was spent with small businesses.

In the six-county area, 39 local jurisdictions exercise the right to levy taxes. These jurisdictions include six counties, five school districts, and 28 cities and towns. Property taxes (real and personal) accounted for approximately 17 percent of total local revenues in 1979, while state and Federal funds accounted for 11 and 8 percent, respectively. Local expenditures on transportation and public works constituted 27 percent of total expenditures in 1979; another 21 percent was expended for public safety.

3.3 GEOLOGY AND SEISMOLOGY

3.3.1 Geology

3.3.1.1 Geologic setting

The SRP is located in the Aiken Plateau physiographic division of the Upper Atlantic Coastal Plain of South Carolina (Cooke, 1936; Du Pont, 1980a). Figure 3-5 shows that the topography in the vicinity of the L-Reactor site at Savannah River Plant is characterized by interfluvial areas with narrow, steep-sided valleys. The relief in the region of the L-Reactor site measures about 20 meters.

The L-Reactor site is about 40 kilometers southeast of the fall line (Davis, 1902) that separates the Atlantic Coastal Plain physiographic province from the Piedmont physiographic province of the Appalachian region (Appendix F, Figure F-1). Crystalline rocks of Precambrian and Paleozoic age underlie the gently seaward-dipping Coastal Plain sediments of Cretaceous and younger age. Sediment-filled basins of Triassic and Jurassic age (exact age is uncertain) occur within the crystalline basement throughout the coastal plain of Georgia and the Carolinas (Du Pont, 1980a). One of these, the Dunbarton Triassic Basin, underlies parts of Savannah River Plant.

3.3.1.2 Stratigraphy

Coastal Plain sediments in South Carolina range in age from Cretaceous to Quaternary; they form a seaward-dipping and thickening wedge of interstratified beds of mostly unconsolidated sediments. At the L-Reactor site, these sediments are approximately 400 meters thick (Siple, 1967). The base of the sedimentary wedge rests on a Precambrian and Paleozoic crystalline basement, which is similar to the metamorphic and igneous rocks of the Piedmont, and on the siltstone and claystone conglomerates of the down-faulted Dunbarton Triassic Basin. Immediately overlying the basement is the Tuscaloosa Formation of Upper Cretaceous age, which is about 230 meters thick and composed of prolific water-bearing sands and gravels separated by prominent clay units. Overlying the Tuscaloosa is the Ellenton Formation, which is about 18 meters thick and consists of sands and clays interbedded with coarse sands and gravel. Four of the formations shown in Figure 3-5--the Congaree, McBean, Barnwell, and Hawthorn--comprise the Tertiary (Eocene and Miocene) sedimentary section, which is about 85 meters thick and consists predominantly of clays, sands, clayey sands, and sandy marls. The near-surface sands of the Barnwell and Hawthorn Formations are usually in a loose to medium-dense state; they often contain thin sediment-filled fissures (clastic dikes) (Du Pont, 1980a).

Quaternary alluvium has been mapped at the surface in floodplain areas. Soil horizons at the site are generally uniform and relatively shallow, about 1 meter deep. They are characterized by bleached Barnwell-Hawthorn sediments, which result in a light tan sandy loam.

Section 3.4.2 and Appendix F present additional stratigraphic information.

3.3.2 Seismology

3.3.2.1 Geologic structures

The Dunbarton Triassic Basin, which is similar to grabens in the Basin and Range Province in Nevada, underlies the Savannah River Plant at the L-Reactor site (Siple, 1967). Other Triassic-Jurassic basins have been identified in the Coastal Plain tectonic province within 300 kilometers of the site (Du Pont, 1980a; Popenoe and Zietz, 1977). The Piedmont, Blue Ridge, and Valley and Ridge tectonic provinces, which are associated with Appalachian mountain building, are northwest of the Fall Line. Several fault systems occur in and adjacent to the Piedmont and the Valley and Ridge tectonic provinces of the Appalachian system; the closest of these is the Belair Fault Zone, about 40 kilometers from the site. The U.S. Nuclear Regulatory Commission has determined that the Belair Fault is not capable within the meaning of 10 CFR 100 (Case, 1977). Studies sponsored by Georgia Power Company have shown that the faults postulated to occur near the southeastern boundary of the Savannah River Plant and about 40 kilometers southeast (Faye and Prowell, 1982) are not capable and that they might not exist (Georgia Power Company, 1982). There is no evidence of any recent displacement along any faults within 300 kilometers of the L-Reactor site (Du Pont, 1980a). In addition, no apparent association exists between local seismicity and specific faults near the Savannah River Plant, with the possible exception of the geophysically inferred faults (Lyttle et al., 1979; Behrendt et al., 1981; Talwani, 1982) in the meizoseismal area of the 1886 Charleston earthquake, which occurred approximately 145 kilometers from the Plant (Du Pont, 1982b).

Surface mapping and subsurface investigations in the L-Reactor region did not detect any faulting of the sedimentary strata or any other geologic hazards that would pose a threat to the reactor. Several surficial faults, generally less than 300 meters in length and with displacements of less than 1 meter, were mapped within several kilometers of the L-Reactor site. None of these faults is considered capable (Du Pont, 1980a).

3.3.2.2 Seismicity

Two major earthquakes have occurred within 300 kilometers of the L-Reactor site: the Charleston earthquake of 1886, which had an epicentral Modified Mercalli Intensity (MMI) of X, was located about 145 kilometers away; and the Union County, South Carolina, earthquake of 1913, which had an epicentral shaking of MMI VII to VIII, was located approximately 160 kilometers away (Langley and Marter, 1973). An estimated peak horizontal shaking of 7 percent of gravity (0.07g) was calculated for the site during the 1886 Charleston earthquake (DOE, 1982a). No reservoir-induced seismicity is associated with Par Pond (see Figure 3-2) (Du Pont, 1982b).

Probabilistic and deterministic analyses commensurate with the criteria used by NRC (10 CFR 100) have established a design-basis earthquake acceleration of 0.20g for key seismic-resistant buildings at Savannah River Plant. This acceleration is predicted to be exceeded only once in about 5000 years (Du Pont, 1982b). (See Section 4.2.2.3.)

3.4 HYDROLOGY

3.4.1 Surface-water hydrology

3.4.1.1 Savannah River

The Savannah River Plant (SRP) is drained almost entirely by the Savannah River, one of the major drainage networks in the southeastern United States (Langley and Marter, 1973). The peak historic flood between 1796 and 1983--10,190 cubic meters per second--corresponds to a stage of about 36 meters (DOE, 1982a), which is about 40 meters below the elevation of L-Reactor. A domino-type failure of dams on the Savannah River above Savannah River Plant would produce a flow of 42,500 cubic meters per second with a corresponding stage of 43.6 meters at Savannah River Plant (Du Pont, 1980a), which is well below the elevation of L-Reactor. The two nearest upstream reservoirs, Clarks Hill (completed in March 1953, with 3.1×10^9 cubic meters of storage) and Hartwell (completed in June 1961, with 3.1×10^9 cubic meters of storage), provide power, flood control, and recreational areas. These reservoirs and the New Savannah River Bluff Lock and Dam at Augusta, Georgia, have stabilized the river flow at Augusta to a yearly average of 288.8 cubic meters per second (Bloxham, 1979) and 295 cubic meters per second at Savannah River Plant. Russell Reservoir, which began filling in December 1983, will furnish 1.2 x 10^9 cubic meters of storage to further stabilize Savannah River flows. TC

Since 1963, it has been the operating practice of the U.S. Army Corps of Engineers to attempt to maintain a minimum flow of 178.4 cubic meters per second below the New Savannah River Bluff Lock and Dam at Butler Creek (River Mile 187.4, near Augusta, Georgia) (COE, 1981). During the 18-year period from 1964 to 1981 (climatic years ending March 31), the average of the lowest 7-consecutive-day flow each year measured at the New Savannah River Bluff Lock and Dam was 181 cubic meters per second (Watts, 1982) or about 2.3 cubic meters per second less than at Savannah River Plant (Ellenton Landing, River Mile 156.8).

An extreme value analysis was used to assess low-flow conditions on the Savannah River. Due to the change in the operating practice of the Corps of Engineers in 1963, the annual lowest 7-day flow data for years prior to 1963 were not considered; a 20-year period of record, climatic years 1964 to 1983 (through March), was used in the analysis. Table 3-3 presents the results of this analysis.

Table 3-3. Seven-day low-flow conditions on the Savannah River at Savannah River Plant[a]

Recurrence interval (yrs)	Flow at Ellenton Landing (m^3/sec)
2	182.8
5	168.5
10	159.0
20	149.9
30	144.6
50	138.0

[a]Based on an external distribution that provided the best fit value (0.9909) of the eight extreme value models suggested by Petruaskas and Aagaard (1970).

Figure 3-6 shows the mean monthly flow rates for the Savannah River measured at Augusta, Georgia from January 1964 through September 1981. Highest flows occur in the winter and spring, and the lowest occur in the summer and fall. Also indicated in this figure are long-term mean and 7-day, 10-year low flows at Ellenton Landing. River flow at Ellenton Landing is usually 9 to 13 cubic meters per second greater than at Augusta, Georgia.

Table 3-4 compares the total river flows at Ellenton Landing for 1979 to 1982. The effects of the 1981 drought are clearly seen. Based on the low-flow analysis (Table 3-3), the drought produced 1-in-50-year 7-day low flows at Savannah River Plant.

Duke Power Company has entered into an agreement with the City of Greenville, South Carolina, to provide an interbasin transfer of as much as 0.53 cubic meter per second in 1985 and 8.3 cubic meters per second by 2020 from Lake Keowee. The States of Georgia and South Carolina have asked the Corps of Engineers for permission to withdraw as much as 1.8 cubic meters per second (total) from Lake Hartwell.

EL-1 The Corps of Engineers maintains, in accordance with its agreement with Duke Power Company, that the interbasin transfer from Lake Keowee to the City of Greenville is legal provided it has no effect on the ability of the Corps to generate electric power at Lake Hartwell and Clarks Hill. The Corps of Engineers is presently assessing the requests by South Carolina and Georgia to withdraw water from Lake Hartwell. This assessment will include the ability of the Corps to maintain its navigation project below the New Savannah Bluff Lock and Dam and to meet its electric-power-generation requirements. It will also consider the effects of the interbasin transfer. Until the Corps of Engineers completes its assessment, it will maintain the flow below the New Savannah Bluff Lock and Dam at the current levels.

TC The 1979-1982 average temperature of the Savannah River 3 kilometers above Savannah River Plant was 17.8°C with a range of 1.5 to 26.0°C (see Table 3-4). Similarly, below Savannah River Plant the average temperature was 18.4°C and the range was 6.5 to 26.0°C. Monthly average daily-maximum temperatures above and below Savannah River Plant for the period 1960-1970 are presented in Figure 3-7. The river temperature increased by 1.1°C on the average over the 40 river miles between Ellenton Landing and the U.S. Highway 301 bridge. This was due, in part, to the natural warming as the water tended toward its equilibrium temperature; discharges from Clarks Hill Lake were typically about 5°C cooler than the water temperatures prior to dam construction (Neill and Babcock, 1971).

As shown in Figure 3-7, June, July, August, and September are the warmest river temperature months; monthly average temperatures and standard deviations are listed in Table 3-5. The average river temperature during these months was about 25 percent higher than the annual average river temperature. From June 1955 through September 1982, the river temperature at Ellenton Landing equalled or exceeded 28°C three times and equalled or exceeded 28.3°C once.

TC Table 3-5. Mean maximum daily temperature, 1960-1969 (°C)

Month	Ellenton Landing Monthly average	Ellenton Landing Standard deviation	Highway 301 bridge Monthly average	Highway 301 bridge Standard deviation
June	21.0	1.5	22.9	2.2
July	22.7	0.7	24.8	1.3
August	23.1	0.7	25.1	1.0
September	22.3	0.9	23.9	1.0

During the February, March, April, and May fish spawning season the monthly average daily-maximum temperatures and standard deviations at Ellenton Landing for the same period of record were 8.7°C and 1.0°C, 11.0°C and 1.3°C, 15.4°C and 1.3°C, and 18.8°C and 1.6°C, respectively.

3.4.1.2 SRP streams and swamp

The SRP site is drained almost entirely by five principal systems (drainage areas are in parentheses): (1) Upper Three Runs Creek (490 square kilometers); (2) Four Mile Creek (including Beaver Dam Creek) (90 square kilometers); (3) Pen Branch (90 square kilometers); (4) Steel Creek (90 square kilometers); and (5) Lower Three Runs Creek (470 square kilometers). These streams rise on the Aiken Plateau and descend 30 to 60 meters before discharging to the Savannah River. The sandy soils of the area permit rapid infiltration of rainfall; seepage from these soils furnishes the streams with a rather constant supply of water through most of the year (Langley and Marter, 1973).

Upper Three Runs Creek is the only major onsite stream that has never received thermal discharges (Du Pont, 1982a). One of the principal tributaries of Upper Three Runs Creek, Tims Branch, received process and nonprocess liquid effluents (from the 700-A and 300-M Areas of Savannah River Plant) of about 0.05 cubic meter per second until May 1982. After this time, discharges of wastewater effluents from M-Area (0.016 cubic meter per second) were diverted to the M-Area basin.

Lower Three Runs Creek has the second largest watershed of the SRP streams. In 1958, its headwaters were impounded to form Par Pond for the recirculation of cooling water from P- and R-Reactors. Cooling water from P-Reactor was discharged to Steel Creek until 1963, when it was diverted to Par Pond. Four Mile Creek receives nonthermal discharges from F- and H-Separations Areas and thermal discharges from C-Reactor. Pen Branch receives thermal discharges from K-Reactor. Reactor secondary cooling-water effluent is discharged at a rate of 11 cubic meters per second.

The L-Reactor site is drained by both Steel Creek and Pen Branch. Steel Creek has been used in the past to receive the reactor coolant discharge. The headwaters of Steel Creek rise near P-Area and flow southwesterly for about 7 kilometers, turn south for about 9 kilometers, and enter the Savannah River swamp about 3 to 5 kilometers from the river. A delta of about 100 acres surrounded by a partial tree-kill zone of another 180 acres has developed where the creek enters the swamp (Du Pont, 1983b). Beyond the delta, Steel Creek is joined by the flow from Pen Branch and some flow from Four Mile Creek before it discharges into the Savannah River near Steel Creek Landing (see Figure 3-2).

TC During the 1983 water year (October 1982 through September 1983), the flow of Steel Creek at Road B ranged between 0.28 and 3.96 cubic meters per second. The average flow for this period was 0.62 cubic meter per second. Of this average flow, about 0.45 cubic meter per second was discharged from P-Reactor at near-ambient temperatures (McAllister, 1983). Farther downstream at Cypress Bridge, about 2.8 kilometers below Road A, the average flow of Steel Creek for calendar years 1978 through 1980 was 1.36 cubic meters per second. After subtracting the P-Reactor contribution, the natural flow of Steel Creek at Cypress

Bridge is calculated to be about 0.91 cubic meter per second. Du Pont (1982a) estimated the natural flow of Steel Creek to be 1.0 cubic meter per second, based on drainage area considerations. Maximum daily flow rates (both natural and with discharges from P-Reactor) were measured between 4.2 and 8.2 cubic meters per second during the past 8 years. TC

As listed in Table 3-6, Steel Creek has had a varied history with respect to the release of reactor effluents. The release of thermal effluents into Steel Creek from L- and P-Reactors reached a peak of about 23 cubic meters per second in 1961. In 1963, P-Reactor effluents were diverted to Par Pond, and thermal discharges to the creek were reduced to about 11 cubic meters per second, about 1.3 times the maximum flow expected at Cypress Bridge after heavy rains. Since 1968, Steel Creek has received only infrequent and short-term inputs of thermal effluents (Smith, Sharitz, and Gladden, 1981, 1982a; Du Pont, 1982a).

Table 3-6. Reactor-Area discharges to Steel Creek[a]

Years	Discharge (m^3/sec)		
	P-Reactor	L-Reactor	Total
1954 to 1958	5.6	5.7	11.3
1958 to early 1961	9.3	9.3	18.6
Mid-1961	11.3	11.3	22.6
Late 1961 to late 1963	9.3	11.3	20.6
November 1963 to February 1968	0.4[b]	11.3	11.7
February 1968 to 1980	0.4[b]	0.0	0.4[b]
1981 to present	0.5[b]	0.002[c]	0.5[b,c]

[a]Adapted from Du Pont (1982a).
[b]Flow from P-Area sources at about ambient temperature.
[c]Flow from sanitary and domestic sources from L-Area at ambient temperature. During cold-water testing, the flow has approached 6.2 cubic meters per second.

Table 3-7 compares stream characteristics before and after Steel Creek received heated discharges from L- and P-Reactors. Between 1951 and 1972, the Steel Creek channel width increased more than three times due to effluent scour.

The three streams that have received the greatest input of thermal effluent (Four Mile Creek, Pen Branch, and Steel Creek) flow into a contiguous swamp of about 10,240 acres (Du Pont, 1983b) that is separated from the main flow of the Savannah River by a 3-meter-high natural levee along the river bank. These streams generally flow as shallow sheets, with well-defined channels only where they enter the swamp and near breaches in the levee (Smith, Sharitz, and Gladden, 1981). The combined natural flow and reactor effluent discharges have a strong influence on water levels in the swamp during nonflood conditions.

The flow of water in the swamp is altered when the Savannah River is in flood stage (about 27.7 meters) with a flow rate of about 440 cubic meters per second. Under flooding conditions, Four Mile Creek, Pen Branch, and Steel Creek

Table 3-7. Steel Creek stream characteristics[a]

Date	Width (m)	Average depth (m)	Flow rate (m^3/sec)	Temperature (°C)
May 1951	5.1	0.30	0.59[b]	16.1
June 1972	16.5	0.37	0.79	24.6

[a]Based on measurements taken at Road A and adapted from Du Pont (1982a).
[b]July 1951 determination.

discharge to the Savannah River at Little Hell Landing after crossing an offsite swamp (Creek Plantation Swamp). An analysis of the data from 1958 through 1980 indicates that on the average the Savannah River reaches flood stage at the Savannah River Plant 79 days, or 22 percent of each year, predominantly from January through April (see Figure 3-6). This result is in agreement with the results of a similar analysis performed by Langley and Marter (1973).

3.4.1.3 Surface-water use

The Savannah River downstream from Augusta, Georgia, is classified by the State of South Carolina as a Class B waterway, suitable for agricultural and industrial use, the propagation of fish, and--after treatment--domestic use. The river upstream from the Savannah River Plant supplies municipal water for Augusta, Georgia, and North Augusta, South Carolina. Downstream, the Beaufort-Jasper Water Authority in South Carolina (River Mile 39.2) withdraws about 19,700 cubic meters per day (0.23 cubic meter per second) to supply domestic water for a population of about 51,000. The Cherokee Hill Water Treatment Plant at Port Wentworth, Georgia (River Mile 29.0), withdraws about 116,600 cubic meters per day (1.35 cubic meters per second) to supply a business-industrial complex near Savannah, Georgia, that has an estimated consumer population of about 20,000 (Du Pont, 1982a). Plant expansions for both systems are planned for the future.

The Savannah River Plant currently withdraws a maximum of 26 cubic meters per second (about 63 percent of the maximum pumping rate of 41 cubic meters per second) from the river, primarily for use as cooling water in production reactors and coal-fired power plants (Du Pont, 1982a). Almost all of this water returns to the river via SRP streams (Du Pont, 1981b). The river receives sewage treatment effluents from Augusta, Georgia, and North Augusta, Aiken, and Horse Creek Valley, South Carolina, and other waste discharges along with the heated cooling water from Savannah River Plant via its tributaries. The cooling-water withdrawal and discharge rate of about 1.2 cubic meters per second for both units of the Alvin Vogtle Nuclear Plant is expected later in the 1980s (Georgia Power Company, 1974). The Urquhart Steam Generating Station at Beech Island withdraws approximately 7.4 cubic meters per second of once-through cooling water. Upstream, recreational use of impoundments on the Savannah River, including water contact recreation, is more extensive than it is near Savannah

River Plant and downstream. No uses of the Savannah River for irrigation have been identified in either South Carolina or Georgia (Du Pont, 1982a).

The water quality of the Savannah River is discussed in Chapter 4. Historic data demonstrate that the water quality of the river downstream of Savannah River Plant is similar to the water quality upstream.

3.4.2 Subsurface hydrology

3.4.2.1 Hydrostratigraphic units

Three distinct hydrogeologic systems underlie Savannah River Plant: (1) the Coastal Plain sediments, where water occurs in porous sands and clays; (2) the buried crystalline metamorphic rock beneath the sediments, where water occurs in small fractures in schist, gneiss, and quartzite; and (3) the Dunbarton Basin (Triassic age) within the crystalline metamorphic complex, where water occurs in intergranular spaces in mudstones and sandstones. The latter two systems are unimportant as ground-water sources near SRP.

The Coastal Plain sediments, which contain several prolific and important aquifers, consist of a wedge of stratified sediments that thickens to the southeast. Near L-Reactor, the sediments are about 400 meters thick and consist of sandy clays and clayey sands. The sandier beds form aquifers and the clayier beds form confining beds. The Coastal Plain sediments across the SRP generally consist of the Barnwell (combined with the Hawthorn as one mapping unit), McBean, Congaree, Ellenton, and Tuscaloosa Formations (Figure 3-5). Among these, the Tuscaloosa Formation is a particularly prolific ground-water unit because of both its thickness, approximately 180 meters beneath H-Area, and its high permeability. Surficial deposits, including terrace sediments and alluvium, are not important sources of ground water at SRP. The lithology and water-bearing characteristics of the hydrostratigraphic units underlying Savannah River Plant are described in Table 3-8. Additional detail is provided in Table F-1 and the text of Appendix F.

Ground water beneath the central portions of the SRP, including the L-Area, generally occurs under confined (artesian) conditions; in wells, the ground water rises to a potentiometric (piezometric) level above the water level encountered in the formation. However, ground water in the Barnwell Formation and overlying units generally occurs under unconfined (water table) conditions; in wells, this ground water remains at the level encountered in the formation. The elevation of the free-standing ground water above a sea-level datum is referred to as the "head."

In the central part of the Savannah River Plant [including the Separations (F- and H-) Areas and the L-Area], the Barnwell and McBean Formations and the McBean and Congaree Formations (Figure 3-8) are separated by layers informally called the "tan clay" and the "green clay," respectively, in SRP studies. The lowest unit of the Barnwell Formation is the tan clay. Borings in the Separations Areas and about 2 kilometers east of the Central Shops (Figure 3-2) indicate that the tan clay is about 2 meters thick, and that it commonly consists of two thin clay layers separated by a sandy zone (D'Appolonia, 1980; Du Pont, EL-11

1983c). In the L-Area, the tan clay is not readily evident from foundation borings, drillers, logs, or geophysical logs; however, even in other SRP areas where it supports a significant head difference, this clay is not always apparent in soil cores.

The green clay, deposited under marine conditions and therefore expected to be continuous over large areas, is hydrogeologically significant because it supports a large head difference between ground water in the McBean and ground water in the Congaree Formations; this head difference is as much as 21 meters near the Central Shops and 24 meters in the Separations Areas, even though the clay is only 2 to 3 meters thick (D'Appolonia, 1980; Du Pont, 1983c). The green clay is effective in preventing the downward migration of contaminants (based on tritium measurements) from the McBean into the Congaree in H-Area (Marine, 1965). This observation is supported by recent analyses of ground water from well 35-D (see the boring location on Figure F-34). During investigations on the capability of the postulated Millett fault, the green clay near P-Area was correlated with the Blue Bluff Member of the Lisbon Formation in Georgia EL-11 (Georgia Power Company, 1982); in the southeastern part of SRP downdip from the Separations Areas, the green clay is believed to be about 18 meters thick (Du Pont, 1983c). Based on geophysical logs of water wells in the L-Area (see Figure F-24), the green clay is about 7 meters thick. At the Par Pond pumphouse, along the strike from L-Reactor, the green clay also supports a large head difference; it also appears to have effectively protected the Congaree ground water from the large (27,000 picocuries per liter) concentrations of tritium in Par Pond (Ashley and Zeigler, 1979). In the central part of SRP, this clay directs much of the water in the McBean laterally to local creeks.

Up dip from the Separations Areas, the tan clay seems to be absent from the stratigraphic section and the green clay is discontinuous. However, in A-Area the green clay might be sufficiently continuous to affect ground-water flow patterns. The ground-water flow direction is to the west-southwest in the water table. Lower in the Tertiary section, the predominant flow is to the south.

Throughout the SRP, the clay at the base of the Congaree and the upper clay layer of the Ellenton Formation provide an effective confining unit for the sands of the Ellenton-upper Tuscaloosa aquifer (see Table F-1).

As shown on Figure 3-8, the heads in the Ellenton and Tuscaloosa Formations are higher than those in the Congaree (upward head differentials) in the central portion of SRP, thus preventing downward movement of water from the Congaree to the Ellenton. This condition is caused by the drawing down of the head in the Congaree by natural drainage into Upper Three Runs Creek and the Savannah River. An approximation of the area where the head difference is upward from the Tuscaloosa to the Congaree is shown in Figure 3-9. F-, H-, and L-Areas are within this area, but M-Area is not.

The head relationships in the Coastal Plain sediments in the northwest part of Savannah River Plant (M-Area) are quite different from those near the L-Reactor. In this updip area, the green clay is discontinuous and is thinner than it is farther downdip, and the tan clay (Figure 3-8) has disappeared entirely. Thus, there is less impedance to downward vertical flow within the Tertiary sediments. Another important factor is that the hydrologic conductivity of the Congaree Formation in M-Area is less than that in the central part of Savannah River Plant because the sediments near M-Area are not as well sorted. As a result of these hydrogeologic characteristics, water elevations decrease with increasing depth from the Congaree to the Tuscaloosa in M-Area (i.e., a downward head differential exists between the Congaree and Tuscaloosa Formations). Closer to the Savannah River, the natural discharge from the Congaree draws its head down below that of the Tuscaloosa. This is an important factor in reducing the likelihood that any surface contamination will enter the important, prolific Tuscaloosa aquifer from the Congaree.

The locations of areas where there is a head reversal between the Congaree and the Tuscaloosa Formations (i.e., the latter's head being higher than the former's) are shown in Figure 3-9; these relationships are general and are not valid in the vicinity of production wells. This head difference map shows that the head in the Tuscaloosa is higher than the head in the Congaree in a broad area within about 10 kilometers of the Savannah River and Upper Three Runs Creek. The head in the Congaree is higher than that of the Tuscaloosa in an area surrounding A- and M-Areas and in the vicinity of Par Pond.

In the L-Reactor area, the water table is generally 3 to 6 meters below the ground surface (Appendix F, Figure F-24). Shallow ground water beneath the L-Reactor area generally moves to the south-southeast in the direction of Steel Creek and to the west-southwest in the direction of Pen Branch (Figure 3-10).

A more detailed discussion of the hydrostratigraphic units and their head relationships across the entire site and in specific areas is given in Appendix F and in Du Pont (1983c).

3.4.2.2 Ground-water movement

Water moves through the ground from areas of high potential energy (usually measured by the combined elevation and pressure heads) to areas of lower energy. In general, on the Atlantic Coastal Plain, the gradient is seaward from the higher areas of the Aiken Plateau toward the continental shelf. Of major significance is the modification of this general southeastward movement caused by the incision of the Savannah and Congaree Rivers and, on a local basis, the incision of the smaller tributaries to these rivers. Ground water in the regions of these rivers and tributaries is diverted toward the hydraulic-energy low caused by natural discharge to the surface water. The depth of dissection at Savannah River Plant by the southwestward-flowing site streams has a significant influence in the direction of flow in most hydrostratigraphic units. The direction of flow in the shallow ground water is most affected by small streams; the direction of flow in the deeper ground water is most affected by major tributaries. The direction of flow in the Ellenton and Tuscaloosa Formations is affected only by the Savannah River itself. Locally, the normal direction of ground-water flow in any unit is modified by ground-water withdrawals from wells.

The energy levels (heads) of the Tuscaloosa Formation, the primary aquifer in the region, and the location of its outcrop areas, are shown in Figures 3-5 and F-1 (Appendix F). Where the outcrop area is high in elevation, as on the Aiken Plateau in the northeast sector of SRP (Figure F-1), water naturally recharged to the Tuscaloosa Formation exceeds the water naturally discharged to local streams, and this excess water moves southeastward through the aquifer.

Where the outcrop area is low in elevation, such as along the Savannah River Valley in the northwest sector of the SRP, water naturally discharges from the formation to the river. Under the Savannah River Plant the direction of Tuscaloosa ground-water movement is southwesterly toward the outcrop of this formation in the Savannah River Valley (Figure F-25). The Ellenton Formation, which lies above the Tuscaloosa, is apparently hydraulically connected to the Tuscaloosa Formation, and its flow pattern is probably similar.

At the Savannah River Plant, the recharge of the Congaree is from offsite areas and from infiltration of precipitation; the higher formations at the Plant are recharged from infiltration of precipitation (about 40 centimeters per year) (Root, 1983). However, discharge into Upper Three Runs Creek and the Savannah River has a dominant effect on Congaree ground-water flow paths. As discussed in Section 3.4.2.1, the energy levels (heads) in the Congaree are lower than those in the Tuscaloosa over much of Savannah River Plant, precluding any downward infiltration in these areas. TC

On a regional basis, the dissecting creeks divide the ground water in the Congaree and higher formations into discrete or compartmentalized subunits. Depending on the depth of dissection, ground water is confined to its own subunit. Even though the hydraulic characteristics of the formations may be similar throughout the area, each subunit has its own natural recharge and discharge areas. The directions of ground-water flow within the Congaree Formation are shown in Figure F-26.

In the central part of Savannah River Plant, the only stream that cuts into the Congaree is Upper Three Runs Creek. The McBean is incised by Upper Three Runs Creek, several of its larger tributaries, Four Mile Creek, Pen Branch, and Steel Creek. Thus, ground water that enters the McBean Formation over much of the interior of Savannah River Plant is restricted in its connection with other subunits of the McBean because of stream incision.

At Savannah River Plant, the water table is commonly within the Barnwell Formation, although in the creek valleys it successively occupies positions in the lower formations. The surface drainage and topography strongly influence the water-table flow path at any point. Even small tributaries to the larger creeks cause depressions in the water table, diverting ground-water flow towards them. The Hawthorn Formation, which is perhaps the most extensive surficial deposit in this region, is usually unsaturated because of its high permeability. Its flow paths are predominantly vertical, with only short horizontal paths.

Flow pathways within each of the Savannah River Plant areas potentially impacted by L-Reactor operation are summarized in Table 3-9. These include other SRP areas that will support the operation of L-Reactor and, therefore, might be affected by increased support activity. Only in M-Area is there significant potential for water table discharges to reach the major regional aquifer (the Tuscaloosa). A more detailed discussion of site-specific aquifer characteristics, including potentiometric contours and flow paths, is included in Appendix F.

In some localities, drawdown from pumping water production wells in the Tuscaloosa Formation might reduce its water level below that of the Congaree. Thus in a small local area, water could theoretically move from the Congaree

Table 3-9. Flow paths at L-affected areas

Area	Water-table discharge
L-Area	Steel Creek, Pen Branch
L-Area seepage and retention basin	Steel Creek
F- and H-Separation Area	Four Mile Creek, Upper Three Runs Creek
Burial grounds	Four Mile Creek, Upper Three Runs Creek
Central shops	Four Mile Creek, Pen Branch
M-Area	Tim's Branch, Savannah River swamps, Hollow Creek (northwest of SRP), vertically

through the Ellenton into the Tuscaloosa. However, such areas do not underlie
TE| L-, K-, and F-Area seepage basins and the burial grounds or central shops.

3.4.2.3 Ground-water quality

The water in the Coastal Plain sediments tends to be of good quality, suitable for industrial and municipal use with minimal treatment. It is generally soft, slightly acidic, and low in dissolved and suspended solids. Appendix F contains a detailed description of the ground-water quality in the vicinity of the various areas of Savannah River Plant that will be affected by L-Reactor operation.

In December 1983, the computerized Well Data File (WDF) contained records for 6404 wells and borings. The WDF provides a central source of information on well and boring construction, geology, and water quality. As many as 66 variables can be entered for each well. There are currently 620 monitoring wells and 70 production wells in the WDF. The remaining records are for engineering and test borings, grout wells, and about 600 old wells, the exact location and status of which are unknown (locations are known within 100 meters).

Based on pre-SRP well-drilling practices, many of these old wells are believed to have been shallow hand-dug domestic wells. Some probably penetrated
EL-25 the Tuscaloosa, including some drilled flowing wells discovered on SRP in the Savannah River valley. Any open holes, rusted-out casings, or otherwise defective wells can provide a direct route for contaminated surface water or shallow ground water to deeper aquifers, even the Tuscaloosa. Contamination of lower aquifers cannot occur from flowing wells. No hand-dug or abandoned wells are known to exist at or adjacent to L-Reactor or the waste disposal sites of any of its support facilities. In addition, no contamination of the Tuscaloosa aquifer by radionuclides and chlorinated hydrocarbons has been noted in the central portion of the SRP. Contamination of well water by chlorinated hydrocarbons from A-Area wells producing from the Tuscaloosa was confirmed earlier in 1983; these hydrocarbons were used as degreasers in M-Area. The contamination appears to

have resulted from chlorinated hydrocarbons that entered the well annuli from the contaminated, shallow (Tertiary) aquifer in A- and M-Areas, and not from any generalized contamination, of the Tuscaloosa aquifer itself. Additional details are provided in Section 5.1.1.2, Appendix F, and Du Pont (1983c). EL-25

3.4.2.4 Ground-water use

Most municipal and industrial water supplies in Aiken County are developed from the Tuscaloosa Formation, which occurs at shallower depths as the Fall Line is approached. Domestic water supplies in Aiken County are primarily developed from the Barnwell, McBean, and Congaree Formations. In Barnwell and Allendale Counties (Figure 3-4), the Tuscaloosa Formation occurs at increasingly greater depths; some municipal users are therefore supplied from the shallower Congaree and McBean Formations or from their limestone equivalent. In these counties, domestic supplies are developed from the Barnwell and McBean Formations.

Forty-four municipalities and industries within 32 kilometers of the center of Savannah River Plant that presently use more than 18.9 cubic meters per day from ground-water sources have been identified. Total pumpage for these users is about 106,300 cubic meters per day. The locations of these users are shown in Figure F-25; pertinent data are listed in Appendix F, Tables F-8 through F-10. TC

Twenty municipal users were identified, as shown in Table F-8. Talatha community, the municipal user nearest to the center of Savannah River Plant (about 11 kilometers away) uses about 150 cubic meters per day. The largest municipal user is the town of Barnwell, about 26 kilometers away; it uses 15,140 cubic meters per day, some of which is supplied to local industry.

Twenty-four industrial users were identified (refer to Appendix F). Total industrial pumpage from the Tuscaloosa Formation is about 67,300 cubic meters per day. This includes 13 users on the Savannah River Plant. TC

Of the total municipal pumpage of 39,000 cubic meters per day, at least 23,500 cubic meters is from Tuscaloosa Formation and 15,000 cubic meters is from the Congaree Formation. TC

In addition to the large municipal and industrial users, 25 small communities and mobile home parks, 4 schools, and 11 small commercial interests are listed in the files of the South Carolina Department of Health and Environmental Control as users of ground water. Wells serving these and other miscellaneous users are generally equipped with pumps with capacities from 54 to 325 cubic meters per day and do not draw large quantities of water. Most wells draw from shallow aquifers. The total withdrawal for these 40 users is estimated to be about 1000 cubic meters per day. In addition to the municipal and industrial users, there are a number of domestic wells near the Savannah River Plant; many of these wells also draw from the shallow aquifers. Two South Carolina State Parks are within a 30-kilometer radius of the center of Savannah River Plant: Aiken State Park, with seven wells, and Barnwell State Park, with two wells. The Edisto Experimental Station at Blackville pumps an average of 70 cubic meters per day from the Congaree Formation. Several shallow wells produce small quantities of water for guardhouses at the Savannah River Plant. TC

3.4.2.5 Relationship of ground-water use to water levels

Hydrographs of five Tuscaloosa wells and one Ellenton well are shown in Figure 3-11. Five of these wells are located at the Savannah River Plant. The sixth well, AK-183, is located 29 kilometers northwest of the center of SRP in the Tuscaloosa outcrop area and is not influenced by pumpage in the vicinity of SRP. The winter (December, January, and February) precipitation is plotted at the top of Figure 3-11; precipitation during these months is the principal source of ground-water recharge. An exception occurred in the summer of 1964, when, due to abundant precipitation (about twice the mean), recharge continued throughout the summer. As a result, record high-water levels occurred in 1965 and 1966. A low in winter precipitation occurred in 1968, and this resulted in low water levels in 1970. Generally high Tuscaloosa water levels occurred in 1974, but from then until 1982 Tuscaloosa water levels declined. From 1972 to 1981, there was a general decline in the winter precipitation, which might partially account for the declining water levels, as shown by wells AK-183 and P7A. However, since 1975, SRP pumping has increased by about 80 percent, from 14.9 to 27.0 cubic meters per minute.

Figure 3-11 shows the total SRP pumping rate (the highest rates are plotted toward the bottom of the Figure to facilitate a comparison of pumping rates and water levels in monitoring wells). Calculations show that the decline in water levels at monitoring wells P7A, P54, and P3A is related primarily to increased ground-water withdrawal at SRP. The drawdowns at these wells reflect adjustments in equilibrium levels rather than aquifer depletion (i.e., withdrawals and flow from an area exceed the ground-water flux into the area). Near-equilibrium water levels are expected to occur quickly (within 100 days) in response to changes in pumping rates (Mayer et al., 1973).

The current (1983) estimate of the total pumpage from the Tuscaloosa Formation within 32 kilometers of the Savannah River Plant is 63 cubic meters per minute (Figure F-25). Usage within the Marine and Routt (1975) ground-water-flux study area (Figure F-31) is currently about 38.5 cubic meters per minute (11.5 from offplant users and 27 from SRP), and should not exceed the natural
AW-1, ground-water flux, which is conservatively estimated to be 51 cubic meters per
EL-15 minute through the study area. When the F-Area powerhouse is placed in standby status in September 1984, the withdrawal of ground water in F-Area is expected to decrease from 6.44 to 3.41 cubic meters per minute. At that time, the projected usage in the study area will be 35.5 cubic meters per minute.

Ground-water withdrawal in A-Area might decrease in August 1984, when the production air stripper is placed in service in M-Area (see Section F.6). Wastewater from the stripper (about 1.1 cubic meters per minute) will be used in the A-Area powerhouse to augment its process-water requirements.

Siple (1967) indicated that withdrawals from the Tuscaloosa at SRP could reach 37.8 cubic meters per minute without exeeeding allowable drawdown in existing (1960) production wells. Potentially, the aquifer could produce more water if well fields were better designed. In 1960, the SRP pumpage from the Tuscaloosa was about 18.9 cubic meters per minute (Siple, 1967).

As noted in Section F.4.2, the best estimate of the flux when the model was run in 1974 was 110 cubic meters per minute; this value is now conservatively estimated to be 51 cubic meters per minute. However, incremental pumpage since the model study was performed might be enough to affect local water levels as new equilibrium levels are established.

AW-1, EL-15 The decline of water levels in the Tuscaloosa Formation since the mid-1970s has reduced the head reversal at the Congaree Formation that occurs southeast of Upper Three Runs Creek. The upward head differential has declined at a rate of about 0.16 meter per year over the last 10 years, primarily because of increased SRP pumping from the Tuscaloosa. The map of the head difference between the Tuscaloosa and Congaree Formations at Savannah River Plant (Figure 3-9) shows that in 1982 the head reversal was still a general situation in the Savannah and Upper Three Runs Creek valleys.

To illustrate the 1982 vertical head relationship in the central part of the Savannah River Plant, Figure 3-8 compares water levels measured in 1972 with water levels measured on November 7, 1982. Heads in the Barnwell, McBean, and Congaree in 1982 were from 1.0 to 1.5 meters below the 1972 level, but the Tuscaloosa water levels were 2.5 to 3.5 meters below the 1972 level. Even though the upward head differential between the Congaree and the Tuscaloosa Formations was still present, it was reduced. Closer to the Savannah River, the current head differential is about 9 meters, as shown in Figure 3-9.

As water is pumped from an aquifer, the water level in the vicinity of the well must be depressed. The amount of head depression to obtain a given pumping rate depends on the transmissivity of the aquifer. The transmissivity of the Tuscaloosa is very high (i.e., a median value of 1366 cubic meters per day per meter at Savannah River Plant). Thus the cones of depression at the pumping centers for the Tuscaloosa are not areally extensive or very deep. The drawdowns in the vicinity of most 3.5- to 4.0-cubic-meter-per-minute wells in the Tuscaloosa are about 6 to 12 meters. During a pumping test at the Barnwell Nuclear Fuel Plant (Mayer et al., 1973), water was withdrawn from the Tuscaloosa for 60 days at a rate of 10,900 cubic meters per day. A drawdown of about 0.15 meter was observed at SRP monitoring well P54, which is about 9 kilometers from the pumping well.

TC

Even though these cones of water-level depression are not areally extensive, drawdowns of 6 to 12 meters are adequate to negate the upward head differential between the Congaree and Tuscaloosa Formations where it exists (see Sections 4.1.1.3, 5.1.1.4, and F.4.3). In areas where a downward head differential exists, such as M-Area, the drawdowns increase the natural downward head differential in the area immediately around the pumping wells.

EL-12

TC In South Carolina, the direction of ground-water flow in the Tuscaloosa and Congaree Formations is from offsite areas through the SRP to the Savannah River. Similarly, in Georgia the ground-water flow in these formations is toward the river (Figures F-25 and F-26).

3.5 METEOROLOGY AND CLIMATOLOGY

The description of the meteorology of Savannah River Plant (SRP) and of the L-Reactor area is based on data collected at the Savannah River Plant and at

Bush Field, Augusta, Georgia (Du Pont, 1980c, 1982a; NOAA, 1981). Meteorological data tapes for 1975 through 1979 from the onsite meteorological program provided additional data for this analysis.

3.5.1 Regional climatology

The Savannah River Plant has a temperate climate, with mild winters and long summers. The region is subject to continental influences, but it is protected from the more severe winters in the Tennessee Valley by the Blue Ridge Mountains to the north and northwest. The SRP site and the surrounding area are characterized by gently rolling hills with no unusual topographical features that would have a significant influence on the general climate.

Winters are mild and although cold weather usually lasts from late November to late March, less than one-third of the days have a minimum temperature below freezing.

3.5.2 Local meteorology

3.5.2.1 SRP meteorology data system

Meteorological data are collected from a system of seven towers located adjacent to each production area on the plant site and from the WJBF-TV tower located about 15 kilometers northwest of the SRP boundary. The seven towers are instrumented at the stack height of 61 meters with vector vanes designed for turbulence measurements (Kern and Mueller, 1979). The TV tower is instrumented at seven levels (Garrett and Hoel, 1982) with bivanes and fast-response cup anemometers to provide the same type of information as that received from the SRP towers (Kern and Mueller, 1979). Platinum resistance thermometers at each of eight levels on the TV tower provide temperature information in the lowest 300 meters of the atmosphere.

The data measured by this tower system are received in the Weather Center Analysis Laboratory (WCAL) by the PDP 11/40 (Digital Equipment Corporation) minicomputer. The latest two weeks of averaged data are also kept on the computer and made available to the VAX 11/780 (Digital Equipment Corporation) super minicomputer for use with various atmospheric transport and dispersion models.

The data collected from the SRP tower system and the WJBF-TV tower are used for real-time emergency response applications. Quality assurance inspections of meteorological data summaries generated hourly by the VAX 11/780 are routinely conducted. Regular inspection of the data summaries allows early detection of major system malfunctions so that necessary repairs can be made on a timely basis.

Automated quality assurance is incorporated into the system through the use of a quality control computer code (Pendergast, 1980). For each variable of the SRP tower data, a spatial average is calculated, as is the deviation of individual values from the spatial average. Deviations larger than the expected standard deviation of the variable indicate that the variable value is in error, and it is replaced with the new spatial average calculated without the erroneous value. Quality control of the WJBF-TV tower data is accomplished in the same manner after first being adjusted, using standard procedures, to the 61-meter SRP tower height. After corrections are made, data are adjusted back to the original heights.

In addition to the tower data, daily records consisting of maximum and minimum temperatures, rainfall, and continuous measurements of temperature, relative humidity, and pressure are kept. Rain gauges are also located at various locations on the SRP site.

An Echosonde doppler acoustic sounder has also been used and is available to provide real-time information on vertical mixing in the lowest 1 kilometer of the atmosphere (i.e., information on thermals, inversions, and depth of the mixed layer).

Regional and national meteorological data are available in the WCAL through the National Weather Service's Automated Field Operations and Service (AFOS) minicomputer system. Data on the AFOS system are available from any point within the AFOS network and can be received in either alphanumeric or graphic display form.

3.5.2.2 Temperature and humidity

Table 3-10 shows the average and extreme temperatures recorded for the Savannah River Plant. The annual average temperature at Savannah River Plant is 18°C. The monthly average temperature ranges from 7°C in January to 27°C in July (see Table 3-10). The extreme temperatures observed at the SRP site are -16°C and 41°C. The Augusta, Georgia, long-term temperature data are in agreement with the SRP data.

The length of the growing season for the Augusta area is normally 241 days, with the first freeze on November 12 and the last freeze on March 16. Freezing temperatures have been observed, however, as early as October 17 and as late as April 21.

The annual average daily relative humidity ranges from 43 percent to 90 percent for Savannah River Plant.

3.5.2.3 Average wind speed and direction

The average wind speed measured in Augusta from 1951 to 1981 was 3.0 meters per second. The average wind speed recorded at a height of 10 meters on the WJBF-TV tower near Beech Island, about 15 kilometers northwest of the SRP boundary, was 2.5 meters per second from 1976 to 1977. The average monthly wind speed for Augusta, Georgia, is shown in Table 3-11 along with the prevailing wind direction for each month. The monthly and annual average wind speeds for three levels of the television tower are also shown. Calms and wind speeds below 2 meters per second at the 62-meter height occur 15 percent of the time at the H-Area tower and 10 percent of the time at the K-Area tower.

Table 3-10. Average and extreme temperatures at Savannah River Plant, 1961-1981

Month	Average temperature (°C) Daily maximum	Daily minimum	Monthly	Extreme temperature (°C) Record maximum	Record minimum
Jan.	13	2	7	30	-16
Feb.	16	3	9	27	-16
Mar.	20	7	13	32	-12
Apr.	25	12	18	35	0
May	28	16	22	37	5
June	32	19	26	41	9
July	33	21	27	41	14
Aug.	32	21	27	40	13
Sept.	29	18	24	38	5
Oct.	24	12	18	33	-2
Nov.	19	7	13	32	-8
Dec.	15	3	9	28	-11
Year	24	12	18	41	-16

Table 3-11. Average monthly wind speed for Augusta, Georgia, 1951-1981 and WJBF-TV tower, 1966-1977

Month	Mean speed (m/sec)	Prevailing direction	Tower elevation (m) 10	36	91
Jan.	3.2	W	3.0	4.5	6.1
Feb.	3.4	WNW	2.9	4.6	5.8
Mar.	3.6	WNW	3.3	4.5	5.9
Apr.	3.4	SE	2.8	4.2	5.4
May	2.9	SE	2.5	3.7	5.0
June	2.8	SE	2.4	4.0	4.8
July	2.6	SE	2.0	3.1	4.4
Aug.	2.5	SE	2.1	3.2	4.3
Sept.	2.5	NE	2.1	3.3	4.7
Oct.	2.6	NW	2.4	4.1	5.6
Nov.	2.8	NW	2.4	4.1	5.6
Dec.	3.0	NW	2.7	4.4	6.3
Annual	3.0	SE	2.5	3.9	5.3

Annual wind direction frequencies for SRP's H- and K-Areas are shown in the transport plots, Figures 3-12 and 3-13. The figures show the percent of time that the wind blows toward each of 16 directions (22.5° sectors). The data presented with these figures indicate the frequency with which the wind was blowing from the indicated direction. The information presented in these figures was produced from data taken at the 61-meter level (the stack height in most of the production areas) for the H- and K-production areas on the SRP site. Because pollutant dispersion depends on atmospheric stability, wind frequencies are presented for each of seven Pasquill-type stability classes discussed in Appendix B. Annually, the predominant transport is from the west-northwest toward the east-southeast with a secondary maximum from the east-northeast toward the west-southwest. The transport for winter is generally from the northwest toward the southeast. The spring transport is generally from the west toward the east, the summer transport generally toward the southeast through north to northeast, and the autumn transport generally toward the southwest and southeast. Because the pollutant dispersion depends on atmospheric stability, annual wind roses are available for each of seven Pasquill-type stability classes; seasonal wind roses are also available (Hoel, 1983).

3.5.2.4 Precipitation

The average annual rainfall at Savannah River Plant from 1952 through 1978 was about 120 centimeters (Du Pont, 1982a). The average annual rainfall at Augusta from 1941 to 1970 was about 108 centimeters (NOAA, 1981). Table 3-12 lists the means and extremes of precipitation for Savannah River Plant from 1952 to 1982. The maximum monthly precipitation at Savannah River Plant was about 31.6 centimeters, recorded in August 1964. Hourly observations in Augusta show that the intensity of the rainfall is normally less than 1.3 centimeters per hour.

Table 3-12. Precipitation at Savannah River Plant, 1952-1982[a]

Month	Monthly precipitation (cm)		
	Maximum	Minimum	Average
Jan.	25.6	2.3	10.7
Feb.	20.3	2.4	10.9
Mar.	28.0	3.8	12.9
Apr.	21.0	1.5	8.9
May	27.9	3.4	10.8
June	27.9	3.9	11.1
July	29.4	2.3	12.5
Aug.	31.6	2.6	11.7
Sept.	22.3	1.4	10.2
Oct.	27.8	0.0	6.2
Nov.	16.5	0.5	5.9
Dec.	24.4	1.2	9.5
Annual			121.3

[a]Adapted from Du Pont (1983b).